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ORIGINAL ARTICLE

Reference growth curves for Greek infants and preschool children, aged 0–6.7 years

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Abstract

Purpose To construct weight, height, head circumference and body mass index (BMI) percentile growth curves for Greek children 0–6.7 years old and to compare the BMI means and upper limits with both available Greek national and international data.

Methods Data were obtained from six cross-sectional and one longitudinal study, which included single, term healthy neonates, recruited at birth and followed until 6.7 years. A total of 12,619 measurements were performed on 7034 boys and girls from five counties in Greece in 1988–2005. The per gender-age percentile estimations were based on Box-Cox power transformations to normalize the data. BMI values were compared with available national data and with the CDC 2000 Growth Charts, the Euro-Growth Study, WHO 2006 Growth Standards and IOTF BMI values.

Results The mean birth weight was 3.5 kg in boys and 3.3 kg in girls, and all mean levels of body measurements were lower in girls than boys. The per gender-age mean BMI values were closer to the data of the Euro-Growth Study and significantly different from previous national and available international data. The 85th percentile of BMI was found significantly higher than all the international data.

Conclusion These growth curves could serve as an additional reference for Greece. That the 85th BMI percentile of this study was higher than all available data should be seriously addressed. Therefore, the growth patterns of preschool children from the present study could serve as approximate indicative values and assist in assessing the health level of the Greek child population.

Keywords Infant · Children · Preschool · Growth and development · Body weights and measures · Body mass index

Introduction

Physical growth assessment is an integral part of the healthcare of infants and children. However, growth charts are not a sole diagnostic tool but rather contribute to forming an overall clinical impression for the child being measured (CPS 2010). The importance of updated, reliable reference data is undisputable not only for individual monitoring but also for the screening of populations (Gelander 2006). The updated World Health Organization's (WHO) Growth Standards for children 0–5 years, based on data from an international multicenter study, were released in April 2006 and were designed to be used as an international standard (WHO 2006). The significance of the WHO growth standards notwithstanding, national reference data remain essential for the description of a particular population, the detection of secular trends and international comparisons (Cacciari et al. 2002; Duran et al. 2016; Huerta et al. 2006; Li et al. 2016; Nazarova and Kuzmichev 2016; Neyzi et al. 2006). The WHO Child Growth Standard for infants and children up to 5 years was published in April 2006, including data from around 8500 children from six different countries on different continents, between 1997 and 2003. The aim was, for the first time, to construct a standard of how children should grow rather than a traditional growth reference; thus, the enrolled children were exclusively breastfed for the first 4 months and lived in a well-supported health environment (de Onis et al. 2004a; WHO 2006).

Growth during the first 6 years of life is of particular importance as it provides information not only about child and family health but also about future development. It is the age when the stunting process, an issue even in well-off countries,

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can be detected (Liu et al. 2000). The construction of reference growth charts for the first 24 months of life is rather demanding and compares the growth of children who were exclusively breast fed and not. The rapid growth pattern during this period of life, dependent on birth weight and susceptible to the type and amount of nutrition, should be efficiently captured. According to the modified WHO criteria of validity of a population as reference, growth during the first 24 months can be more adequately described using longitudinal data together with frequent assessment of feeding practices than with cross-sectional data (Van't Hof and Haschke 2000a).

Among the growth evaluation indices, the body mass index (BMI), as calculated from basic indices such as weight and height, represents a simple and accurate indicator for monitoring children's body weight. However, a relatively recent survey from 188 countries showed that the most commonly used auxologic indicator worldwide is weight for age (97% of the countries), whereas weight for length/height is used only in 23%, with BMI being used even more rarely (Christoforidis et al. 2011).

In Greece, the need to develop appropriate updated growth references for preschool children, school children and adolescents has been motivated by two contemporary events: the public health concern over the rising incidence of childhood obesity and the lack of national representative epidemiologic data regarding anthropometric measurements of children for these age groups (Tambalis et al. 2015). For several years and until very recently, the NCHS/CDC 1977–1978 percentile curves were in use in Greece for the evaluation of growth of infants and preschool children, as is the case for many other parts of the world, which lack local reference data (de Onis et al. 2004b).

In Greece, percentile curves for the weight, height and head circumference for age derived from a cross-sectional nationwide sample of 27,000 children aged 6–17 years in 1981 was used as the national reference data for this age group until 2003 (Mantzagrioti-Meimarides et al. 1986). Because of the lack of national data for infants and preschool children younger than 6 years, the United States National Center for Health Statistics/Centers for Disease Control and Prevention (NCHS/CDC) 1977–78 percentile curves were accordingly adopted (Kafatos 2007). In 2003, percentile curves, based on a cross-sectional sample of about 10,000 children and adolescents 0.5–18 years old, attending schools and nurseries in the wider Athens area, not including other parts of the country, and a smaller sample of neonates and infants 0–6 months old from neonatal departments and outpatients clinics in the same location, were constructed by the First (A) Paediatric Department of the University of Athens (APDUA). However, the two series of national studies lack a longitudinal component (Chiotis et al. 2003, 2004). Recently, reports from Thessaloniki, North Greece, on 1557 children (mean age, 11.42 ± 3.51 years) revealed that using the national Greek reference standards for BMI underestimated the true prevalence of overweight and obese Greek children, while both the IOTF and CDC criteria, although independently, were detected and increased the number of overweight and obese children. Thus, they should be adopted in clinical practice for earlier identification (Christoforidis et al. 2011). The aim of the present study was to construct percentile curves of height, weight, head circumference and BMI for age for Greek infants and preschool children (0–6.7 years old) from data derived during the era prior to the Greek economic crisis using representative samples of children living in different geographical areas in the country, including a longitudinal component, and to compare the results with reference data from other nations.

Methods

Subjects and data collection

In the present study, data were collected by one longitudinal and six cross-sectional surveys, which included representative samples of 7034 infants and children 0–6.7 years old (birth to 80 months) in Greece (Table 1, Fig. 1). Six of the seven studies were carried out by the Preventive Medicine and Nutrition Clinic of the University of Crete and included children living on the island of Crete (Bitsori et al. 1995; Linardakis et al. 2000, 2008; Mamalakis et al. 2000; Vardavas et al. 2006). The seventh study was carried out by the Department of Nutrition and Dietetics of the Harokopio University of Athens and included infants and children living in five counties widely scattered over the Greek dominion, including the capital Athens, Attica county (Manios 2006). The cross-sectional studies, which involved daycare center, nursery school and primary school attendees, were performed with multistage random sampling. In each study, primary schools and preschool centers were randomly selected, providing that the sample was representative of the total number of schools/preschool centers and urban/rural distribution in each district. Detailed descriptions of the sampling, response rate, exclusion criteria, etc., are provided in the relevant publications (Bitsori et al. 1995; Linardakis et al. 2000, 2008, 2010; Mamalakis et al. 2000; Manios 2006; Vardavas et al. 2006). In brief, the longitudinal study, which is the data source for infants in the present analysis, included single, term neonates without significant morbidity, born on the island of Crete in 1988 and followed up prospectively through 1995 (Linardakis et al. 2000). Mothers were enrolled postpartum at public and private maternity departments in three of the four counties of the island.

Anthropometric measurements

In all studies, measurements of weight, height and head circumference were obtained using standardized common procedures. The details of the measurements and equipment used have been described in the relevant publications

Table 1 Study samples of infants and preschool children used in current study constructing growth curves

Reference	Study type	Data collection period	Age, *months*	Boys **n** (measurements)	Girls
Perinatal Program of Crete (Linardakis et al. 2000)	Longitudinal	1988–1995	0–72	**675** (3512)	**659** (3407)
Growth evaluation-Sitia survey (Bitsori et al. 1995)	Cross-sectional	1989–1992	60–80	**130**	**130**
Health Education Program (Mamalakis et al. 2000; Manios et al. 1998)	Cross-sectional	1992–1993	57–80	**537**	**497**
Metabolic Syndrome Survey (Linardakis et al. 2008)	Cross-sectional	2001/2003	33–80	**106**	**100**
The GENESIS study (Manios 2006)	Cross-sectional	2003–2004	0.8–73	**1218**	**1156**
Kindergardens survey (Linardakis et al. 2010)	Cross-sectional	2004	6–74	**83**	**54**
Chania survey (Linardakis et al. 2010; Vardavas et al. 2006)	Cross-sectional	2004–2005	48–80	**860**	**829**
Total study sample		**1988–2005**	**0–80**	**7034** (12,619)	

(Bitsori et al. 1995; Kafatos et al. 2007; Linardakis et al. 2000, 2008, 2010; Mamalakis et al. 2000; Manios 2006; Vardavas et al. 2006). In brief, children's weight (in kilograms) was measured in a fasting state, wearing underwear but no shoes. Infants and children up to 30 months were weighed nude with a mechanical infant scale (to the nearest ±20 g) before the next meal (Linardakis et al. 2000; Manios 2006). For infants and children younger than 24 months, recumbent length was measured using a portable wooden board with a stationary head piece, a sliding vertical foot piece and a horizontal back piece with a measure tape mounted on it (Linardakis et al. 2000). For children older than 24 months, standing height was measured. Birth weight for infants was recorded at recruitment. Head circumference was measured using a non-elastic tape with the child in supine position until the age of 24 months and in sitting position thereafter. The subjects who participated in the longitudinal study were first measured at age 15 days ± 2 days, and subsequent measurements were scheduled at monthly intervals for the first 3 months, 3-month intervals until

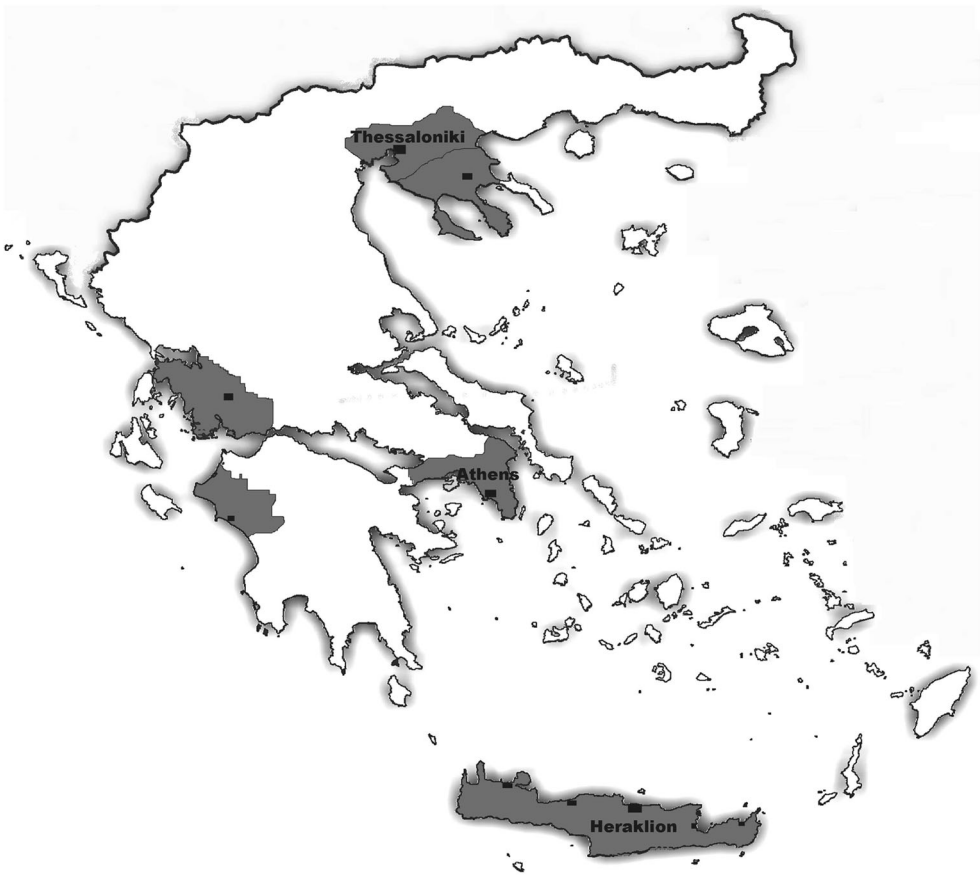

Fig. 1 Map of Greece and selected areas. Samples were taken in the gray areas

Table 2 Mean and standard deviation values for body weight, height, body mass index and head circumference in relation to age

Age (months)	Weight (kg)		Height (cm)		BMI (kg/m^2)		Head circumference (cm)	
	n[a]	Mean (SD)	n	Mean (SD)	n	Mean (SD)	n	Mean (SD)
Boys								
Birth	487	3.5 (0.5)	487	49.3 (2.4)	487	14.2 (1.9)	487	34.3 (1.4)
1	606	4.4 (0.6)	598	54.6 (2.8)	592	14.8 (1.7)	596	37.9 (2.3)
2	499	5.4 (0.7)	483	58.1 (2.9)	483	16.2 (2.2)	490	39.7 (1.6)
3	442	6.3 (0.7)	430	61.3 (2.5)	427	16.8 (1.7)	441	41.1 (1.7)
6	315	8.0 (0.9)	311	68.1 (3.3)	307	17.3 (1.9)	315	44.0 (2.2)
9	250	9.3 (1.0)	245	72.8 (3.2)	242	17.5 (1.7)	252	46.3 (4.0)
12	239	10.3 (1.3)	238	77.2 (4.0)	235	17.4 (1.9)	240	47.2 (1.5)
18	160	12.0 (1.8)	159	84.2 (4.8)	158	17.0 (1.5)	159	48.7 (1.4)
24	186	13.3 (1.7)	180	89.5 (3.5)	180	16.6 (1.7)	187	49.5 (3.1)
30	209	14.7 (2.5)	210	93.7 (3.9)	209	16.7 (2.7)	210	49.9 (1.3)
36	283	16.0 (2.2)	282	98.1 (4.0)	280	16.6 (1.7)	282	50.5 (1.6)
42	327	17.1 (2.4)	327	101.6 (4.1)	327	16.5 (1.8)	326	50.8 (1.4)
48	298	18.5 (3.0)	297	105.4 (4.9)	296	16.6 (2.0)	298	51.2 (1.6)
54	416	19.8 (3.3)	414	110.1 (4.7)	414	16.3 (1.9)	416	51.6 (1.6)
60	353	21.2 (3.8)	353	113.6 (4.9)	353	16.4 (2.0)	349	51.9 (1.5)
66	360	23.0 (4.7)	360	117.2 (5.3)	360	16.6 (2.5)	335	52.3 (1.4)
72	730	23.8 (5.9)	730	119.6 (6.1)	730	16.5 (2.7)	314	52.5 (2.1)
78	268	24.4 (4.7)	268	121.4 (5.2)	268	16.5 (2.3)	–	
Total	6428		6372		6348		5697	
Girls								
Birth	450	3.3 (0.5)	450	48.4 (2.3)	450	13.4 (2.0)	450	33.7 (1.6)
1	570	4.1 (0.5)	559	53.5 (2.5)	551	14.4 (1.9)	563	37.1 (2.2)
2	475	5.0 (0.6)	464	56.8 (2.6)	460	15.4 (1.8)	475	38.7 (1.5)
3	429	5.7 (0.7)	423	59.8 (2.3)	419	16.1 (1.5)	428	39.9 (1.3)
6	320	7.5 (0.8)	310	66.3 (2.8)	308	17.1 (1.7)	318	42.9 (1.8)
9	243	8.7 (0.9)	242	71.1 (3.1)	238	17.3 (1.9)	244	44.9 (2.5)
12	221	9.7(1.1)	219	75.2 (3.3)	214	17.2 (1.6)	224	46.0 (1.4)
18	174	11.4 (1.6)	175	82.2 (3.5)	172	16.9 (2.0)	175	47.5 (1.2)
24	185	13.1 (1.8)	182	88.4 (4.0)	182	16.7 (2.0)	185	48.5 (3.0)
30	197	14.3 (2.0)	196	93.2 (3.9)	195	16.4 (1.8)	198	49.3 (3.7)
36	262	15.5 (2.2)	261	97.4 (4.0)	261	16.3 (1.7)	261	49.6 (1.3)
42	269	16.7 (2.5)	268	101.1 (4.2)	268	16.3 (1.9)	269	49.8 (1.4)
48	287	18.1 (3.1)	288	104.8 (5.0)	286	16.4 (2.0)	289	50.3 (1.5)
54	433	19.4 (3.3)	433	108.5 (4.7)	433	16.4 (2.0)	433	50.7 (1.4)
60	341	20.7 (4.2)	341	112.1 (4.9)	341	16.4 (3.0)	340	51.0 (1.4)
66	367	21.9 (3.9)	367	116.0 (5.0)	367	16.2 (2.1)	342	51.3 (1.6)
72	677	23.1 (4.8)	676	118.5 (5.9)	676	16.3 (2.4)	263	51.5 (1.4)
78	232	23.7 (4.3)	232	120.3 (5.3)	232	16.3 (2.2)	–	
Total	6132		6086		6053		5457	

Age, after the first year, was estimated from reference month ± 3 months

[a] *n* is the maximum number of cases for each measurement and age

12 months and 6-month intervals thereafter until the age of 72 months (6 years). Birth weight was recorded from the maternity record of each infant. Nearly 41% of the infants were exclusively breast-fed at birth, but only 9% continued by 6 months. BMI was calculated as weight (kilograms) divided by square height (square meters).

Table 3 L, M and S parameters of body weight, height, body mass index and head circumference in relation to gender and age

Age (months)	Weight			Height			BMI			Head circumference		
	L	*M*	*S*	*L*	*M*	*S*	*L*	*M*	*S*	*L*	*M*	*S*
Boys												
Birth	1.605	3.677	0.138	5.279	55.856	0.051	0.545	15.823	0.111	1.057	40.074	0.061
1	1.482	4.485	0.136	5.052	56.565	0.051	0.470	15.878	0.110	1.033	40.667	0.060
2	1.361	5.268	0.135	4.517	58.542	0.050	0.390	15.979	0.110	1.010	41.011	0.060
3	1.245	6.002	0.133	3.984	60.507	0.050	0.310	16.078	0.109	0.986	41.354	0.059
4	1.135	6.676	0.131	3.459	62.445	0.050	0.231	16.173	0.108	0.962	41.696	0.058
5	1.030	7.293	0.130	2.947	64.346	0.050	0.153	16.265	0.108	0.938	42.037	0.058
6	0.931	7.859	0.129	2.452	66.201	0.050	0.075	16.351	0.107	0.915	42.375	0.057
7	0.837	8.376	0.128	1.980	68.001	0.049	−0.001	16.431	0.107	0.891	42.710	0.057
8	0.747	8.853	0.127	1.533	69.743	0.049	−0.076	16.504	0.106	0.867	43.041	0.056
9	0.661	9.295	0.126	1.114	71.423	0.049	−0.149	16.569	0.106	0.843	43.368	0.056
10	0.579	9.705	0.126	0.725	73.039	0.049	−0.221	16.627	0.105	0.820	43.690	0.055
11	0.500	10.090	0.125	0.369	74.591	0.049	−0.291	16.678	0.104	0.796	44.007	0.055
12	0.425	10.451	0.125	0.046	76.079	0.048	−0.360	16.721	0.104	0.772	44.319	0.054
18	0.047	12.262	0.126	−1.194	83.763	0.046	−0.727	16.842	0.101	0.630	46.059	0.051
24	−0.213	13.681	0.128	−1.317	89.685	0.044	−1.021	16.791	0.100	0.487	47.555	0.047
30	−0.403	14.889	0.132	−0.625	94.430	0.043	−1.240	16.658	0.100	0.345	48.796	0.044
36	−0.556	15.999	0.136	0.480	98.566	0.042	−1.380	16.506	0.101	0.202	49.792	0.041
42	−0.692	17.084	0.141	1.613	102.493	0.042	−1.439	16.372	0.103	0.060	50.570	0.038
48	−0.823	18.186	0.147	2.365	106.396	0.043	−1.413	16.269	0.108	−0.082	51.171	0.035
54	−0.943	19.312	0.153	2.413	110.214	0.044	−1.301	16.204	0.113	−0.225	51.641	0.032
60	−1.045	20.445	0.160	2.027	113.754	0.045	−1.100	16.174	0.119	−0.367	52.025	0.030
66	−1.127	21.566	0.167	1.387	116.919	0.047	−0.823	16.162	0.127	−0.510	52.362	0.027
72	−1.194	22.667	0.174	0.625	119.738	0.048	−0.503	16.161	0.135	−0.652	52.681	0.025
78	−1.255	23.760	0.181	0.015	122.379	0.050	−0.190	16.174	0.142	−0.795	52.996	0.022
Girls												
Birth	1.662	3.430	0.128	−0.660	54.731	0.065	0.617	15.296	0.107	1.006	38.956	0.057
1	1.514	4.162	0.128	−0.631	56.674	0.065	0.546	15.357	0.107	0.987	39.587	0.057
2	1.369	4.875	0.127	−0.602	58.026	0.065	0.463	15.479	0.107	0.967	39.942	0.056
3	1.229	5.551	0.126	−0.573	59.378	0.065	0.381	15.600	0.107	0.948	40.295	0.056
4	1.096	6.182	0.126	−0.544	60.726	0.064	0.300	15.717	0.107	0.929	40.648	0.055
5	0.969	6.767	0.125	−0.515	62.070	0.064	0.220	15.830	0.107	0.909	40.998	0.055
6	0.850	7.310	0.125	−0.486	63.406	0.064	0.141	15.937	0.107	0.890	41.346	0.054
7	0.739	7.811	0.125	−0.457	64.735	0.064	0.064	16.038	0.106	0.871	41.691	0.054
8	0.635	8.277	0.125	−0.428	66.053	0.063	−0.012	16.131	0.106	0.851	42.032	0.053
9	0.539	8.712	0.125	−0.399	67.359	0.063	−0.086	16.216	0.106	0.832	42.369	0.053
10	0.449	9.118	0.126	−0.370	68.653	0.063	−0.157	16.293	0.106	0.813	42.701	0.052
11	0.366	9.502	0.126	−0.341	69.932	0.062	−0.227	16.362	0.106	0.793	43.027	0.052
12	0.288	9.864	0.127	−0.312	71.197	0.062	−0.294	16.423	0.106	0.774	43.348	0.051
18	−0.073	11.714	0.131	−0.138	78.440	0.061	−0.647	16.636	0.106	0.658	45.138	0.048
24	−0.307	13.195	0.135	0.036	85.036	0.059	−0.910	16.650	0.106	0.542	46.671	0.045
30	−0.468	14.456	0.140	0.211	90.966	0.058	−1.086	16.551	0.107	0.426	47.936	0.042
36	−0.588	15.600	0.145	0.385	96.264	0.056	−1.193	16.416	0.108	0.310	48.946	0.039
42	−0.686	16.696	0.149	0.559	100.996	0.054	−1.238	16.288	0.111	0.194	49.729	0.036
48	−0.768	17.782	0.154	0.733	105.249	0.053	−1.226	16.182	0.113	0.079	50.327	0.034
54	−0.835	18.874	0.158	0.907	109.116	0.051	−1.170	16.100	0.117	−0.037	50.783	0.031
60	−0.891	19.973	0.163	1.081	112.691	0.050	−1.089	16.040	0.121	−0.153	51.144	0.029

Table 3 (continued)

Age (months)	Weight			Height			BMI			Head circumference		
	L	*M*	*S*	*L*	*M*	*S*	*L*	*M*	*S*	*L*	*M*	*S*
66	−0.938	21.069	0.167	1.255	116.058	0.048	−0.997	15.999	0.125	−0.269	51.449	0.027
72	−0.979	22.155	0.172	1.429	119.298	0.047	−0.902	15.970	0.129	−0.385	51.731	0.024
78	−1.018	23.231	0.176	1.603	122.491	0.045	−0.815	15.945	0.133	−0.501	52.007	0.022

Parameters were estimated for each of the 78 months and presented only for the current age

L lambda for the skewness, *M* mu for the median, *S* sigma for the generalized coefficient of variation

Statistical analysis

To construct growth curve percentiles, the LMS Chart Maker Pro version 2.4 software program was used (Medical Research Council, Institute of Child Health,, London, UK). The estimations of per gender-age percentiles was based on Box-Cox power transformations to normalize the data (Cole et al. 2000; Cole and Green 1992) and using weights because of the different complex samples that were combined in the analysis. All percentiles were extracted for every month of measurement, from birth to 78 months. The BMI cutoff values for the 85th and 95th percentiles were also illustrated, and the 85th percentile was compared with other similar studies, such as the International Obesity Task Force-IOTF study (Cole et al. 2000), the updated 2000 CDC Growth Charts (Ogden et al. 2002), the Euro-Growth Study 2000 (de Onis et al. 2004a; Van't Hof and Haschke 2000a, 2000b) and the updated 2006 WHO Growth Standards study (WHO 2006).

Results

Data from 7034 infants and children (12,619 measurements) were used in the present study for the construction of growth curves. The sample size of each study group, according to gender and age, is shown in Table 1. The mean and standard deviation values for weight, height, head circumference and BMI in relation to age, together with the number of measurements for each gender-age group, are shown in Table 2. There is a gradual increase in BMI during infancy and a very slow decrease thereafter until the age of 4 years, when a slow increasing tendency is noted. The mean birth weight was 3.5 kg for boys and 3.3 kg for girls, and all mean levels of body measurements were lower in girls than boys.

Using the LMS method, Table 3 and Fig. 2 present the L (lambda), M (median) and S (skewness) coefficients of body weight, height, BMI and head circumference in relation to gender and age. The smoothed percentiles from 3rd to 97th (3rd, 10th, 25th, 50th, 75th, 90th, 97th) for weight, height, head circumference and BMI per age-gender are illustrated in Table 4. The median birth weight was 3.7 kg in boys and 3.4 kg in girls, the 97th percentiles 4.6 kg and 4.2 kg, respectively, and 3rd percentiles were higher than or equal to the "low birth weight" definition (2.6 kg and 2.5 kg, respectively). BMI value fluctuation occurs in almost all percentiles as age increases.

Figure 3 presents a comparative illustration of the 85th BMI percentiles of the present study, CDC 2000, Euro-Growth Study, WHO standards and IOTF BMI 25 equivalent. As the figure shows, the 85th BMI percentiles for Greek children of both genders do not compare favorably to any of the studies mentioned. In addition, after the age of 1.5 years, these percentiles are higher than those of their counterparts. The results also seem closer to those of the Euro-Growth Study during the first 18 months of life, which is more apparent in boys, but there is considerable deviation thereafter.

Discussion

The current study is the first to present reference growth charts on body weight, height, head circumference and BMI for Greek preschool aged children 0–6.7 years old based on a combination of cross-sectional and longitudinal data and on measurements from children living in different geographical areas of the country. The data were from a well-designed longitudinal study, which invited participation of all single, term neonates born in three of the four districts of the island of Crete during the whole year of 1988, in private and public maternity departments. To the best of our knowledge, this is the largest study of this kind on the Greek population. Previous studies aiming to construct national growth curves for Greek preschool children were undertaken during the 1980s in Northern Greece (Aivazis 1990) and 4 years ago in Athens (Chiotis et al. 2004; Chiotis et al. 2003). The first study from Northern Greece, despite the adequacy of the sampling size, dating back to the 1980s and being confined to the local child population, might not reflect the current composition of the childhood population in Greece and the change in socioeconomic conditions that has occurred during the last decades with large-scale immigration, mainly from the neighboring Balkan countries. The second recent study from Athens

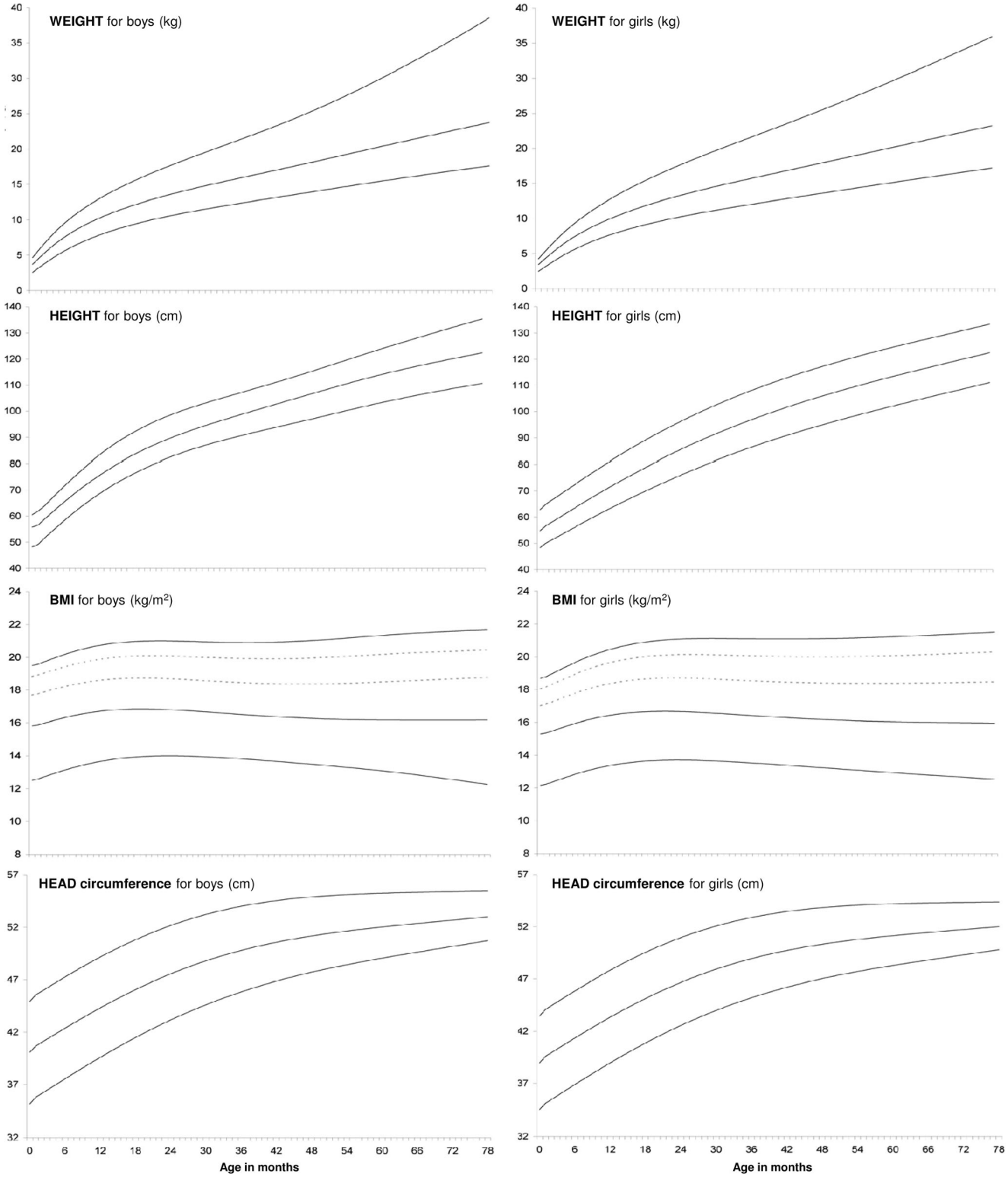

Fig. 2 Smoothed percentile curves of the 3rd, 50th and 97th for weight, height and head circumference or 3rd, 50th, 85th, 95th and 97th for body mass index (BMI) in boys and girls. The dashed and gray lines in body mass index (BMI) present the 85th and 95th percentile curves

(APDUA), presently in use as national reference data, provides an updated image of the current Greek childhood population; however, it only included residents of the capital area (Chiotis et al. 2003, 2004). Both these studies lack a longitudinal component. The mean BMI values of the present study are significantly higher than the mean BMI values of both the

Table 4 Smoothed percentiles for body weight, height, body mass index (BMI) and head circumference in relation to gender and age

	Age, *months*	Weight (kg)							Height (cm)							BMI (kg/m^2)
		3rd	10th	25th	50th	75th	90th	97th	3rd	10th	25th	50th	75th	90th	97th	3rd
Boys	Birth	2.6	3.0	3.3	3.7	4.0	4.3	4.6	48.2	51.2	53.7	55.9	57.7	59.2	60.5	12.5
	1	3.2	3.6	4.1	4.5	4.9	5.3	5.6	49.1	52.1	54.5	56.6	58.4	59.9	61.4	12.6
	2	3.8	4.3	4.8	5.3	5.7	6.2	6.6	51.2	54.0	56.4	58.5	60.4	62.1	63.6	12.7
	3	4.3	4.9	5.5	6.0	6.5	7.0	7.6	53.2	56.0	58.4	60.5	62.4	64.2	65.8	12.8
	4	4.9	5.5	6.1	6.7	7.3	7.8	8.4	55.2	57.9	60.3	62.4	64.4	66.3	68.0	12.9
	5	5.4	6.0	6.7	7.3	7.9	8.6	9.2	57.2	59.8	62.1	64.3	66.4	68.4	70.2	13.1
	6	5.9	6.5	7.2	7.9	8.5	9.2	9.9	59.1	61.6	64.0	66.2	68.3	70.4	72.4	13.2
	7	6.3	7.0	7.7	8.4	9.1	9.8	10.6	60.9	63.4	65.7	68.0	70.2	72.4	74.4	13.3
	8	6.7	7.4	8.1	8.9	9.6	10.4	11.2	62.7	65.1	67.4	69.7	72.0	74.2	76.4	13.4
	9	7.1	7.8	8.5	9.3	10.1	10.9	11.7	64.4	66.7	69.1	71.4	73.8	76.1	78.4	13.5
	10	7.4	8.1	8.9	9.7	10.5	11.4	12.3	66.0	68.3	70.7	73.0	75.4	77.8	80.3	13.5
	11	7.7	8.5	9.3	10.1	11.0	11.8	12.8	67.6	69.9	72.2	74.6	77.0	79.5	82.1	13.6
	12	8.0	8.8	9.6	10.5	11.3	12.3	13.3	69.1	71.3	73.7	76.1	78.6	81.1	83.8	13.7
	18	9.5	10.4	11.3	12.3	13.3	14.5	15.7	76.7	78.9	81.3	83.8	86.4	89.3	92.4	13.9
	24	10.7	11.6	12.6	13.7	14.9	16.3	17.8	82.5	84.7	87.1	89.7	92.4	95.4	98.5	14.0
	30	11.6	12.6	13.7	14.9	16.3	17.9	19.7	86.9	89.3	91.8	94.4	97.2	100.1	103.1	13.9
	36	12.4	13.5	14.6	16.0	17.6	19.4	21.5	90.5	93.1	95.8	98.6	101.3	104.2	107.0	13.8
	42	13.2	14.3	15.6	17.1	18.8	20.9	23.4	93.7	96.7	99.6	102.5	105.3	108.1	110.9	13.7
	48	14.0	15.2	16.5	18.2	20.1	22.5	25.5	96.7	100.1	103.3	106.4	109.4	112.2	115.0	13.5
	54	14.7	16.0	17.5	19.3	21.5	24.2	27.7	99.9	103.5	106.9	110.2	113.4	116.4	119.3	13.3
	60	15.5	16.9	18.5	20.4	22.9	26.0	30.2	103.0	106.7	110.3	113.8	117.1	120.4	123.5	13.1
	66	16.2	17.7	19.4	21.6	24.3	27.9	32.8	105.8	109.6	113.3	116.9	120.5	124.1	127.6	12.8
	72	16.9	18.5	20.3	22.7	25.7	29.8	35.6	108.3	112.1	115.9	119.7	123.6	127.6	131.6	12.6
	78	17.6	19.2	21.2	23.8	27.1	31.7	38.5	110.7	114.4	118.3	122.4	126.6	130.9	135.3	12.3
Girls	Birth	2.5	2.8	3.1	3.4	3.7	4.0	4.2	48.3	50.3	52.4	54.7	57.2	59.9	62.8	12.2
	1	3.0	3.4	3.8	4.2	4.5	4.8	5.2	50.0	52.1	54.3	56.7	59.2	62.0	64.9	12.2
	2	3.6	4.0	4.5	4.9	5.3	5.7	6.1	51.2	53.3	55.6	58.0	60.6	63.4	66.4	12.4
	3	4.1	4.6	5.1	5.6	6.0	6.5	6.9	52.4	54.6	56.9	59.4	62.0	64.9	67.9	12.5
	4	4.6	5.1	5.7	6.2	6.7	7.2	7.7	53.6	55.8	58.2	60.7	63.4	66.3	69.4	12.6
	5	5.1	5.6	6.2	6.8	7.3	7.9	8.5	54.8	57.1	59.5	62.1	64.8	67.7	70.9	12.7
	6	5.5	6.1	6.7	7.3	7.9	8.5	9.2	56.0	58.3	60.8	63.4	66.2	69.2	72.3	12.8
	7	5.9	6.5	7.2	7.8	8.5	9.1	9.8	57.2	59.6	62.1	64.7	67.6	70.6	73.8	12.9
	8	6.3	6.9	7.6	8.3	9.0	9.7	10.4	58.4	60.8	63.3	66.1	68.9	72.0	75.2	13.0
	9	6.7	7.3	8.0	8.7	9.5	10.2	11.0	59.6	62.0	64.6	67.4	70.3	73.4	76.7	13.1
	10	7.0	7.7	8.4	9.1	9.9	10.7	11.6	60.7	63.2	65.9	68.7	71.6	74.7	78.1	13.2
	11	7.3	8.0	8.7	9.5	10.3	11.2	12.1	61.9	64.4	67.1	69.9	72.9	76.1	79.5	13.3
	12	7.6	8.3	9.1	9.9	10.7	11.6	12.6	63.0	65.6	68.3	71.2	74.2	77.4	80.8	13.4
	18	9.0	9.9	10.7	11.7	12.8	14.0	15.2	69.5	72.4	75.3	78.4	81.7	85.1	88.7	13.6
	24	10.2	11.1	12.1	13.2	14.5	15.9	17.5	75.5	78.6	81.7	85.0	88.5	92.0	95.7	13.7
	30	11.1	12.1	13.2	14.5	15.9	17.6	19.5	81.0	84.2	87.5	91.0	94.5	98.2	101.9	13.7
	36	11.9	13.0	14.2	15.6	17.2	19.1	21.4	85.8	89.2	92.7	96.3	99.9	103.6	107.4	13.5
	42	12.7	13.9	15.2	16.7	18.5	20.7	23.3	90.3	93.8	97.4	101.0	104.7	108.5	112.3	13.4
	48	13.5	14.7	16.1	17.8	19.8	22.2	25.2	94.3	97.9	101.6	105.2	109.0	112.7	116.5	13.2

Table 4 (continued)

	Age, *months*	Weight (kg)							Height (cm)							BMI (kg/m^2)
		3rd	10th	25th	50th	75th	90th	97th	3rd	10th	25th	50th	75th	90th	97th	3rd
	54	14.3	15.5	17.1	18.9	21.1	23.8	27.3	98.0	101.7	105.4	109.1	112.9	116.6	120.4	13.1
	60	15.0	16.4	18.0	20.0	22.4	25.4	29.3	101.4	105.2	108.9	112.7	116.4	120.2	123.9	12.9
	66	15.7	17.2	18.9	21.1	23.7	27.1	31.5	104.7	108.5	112.3	116.1	119.8	123.5	127.1	12.8
	72	16.5	18.0	19.9	22.2	25.0	28.7	33.7	107.9	111.8	115.6	119.3	123.0	126.6	130.2	12.7
	78	17.2	18.8	20.8	23.2	26.3	30.4	35.9	111.1	115.0	118.8	122.5	126.1	129.7	133.3	12.5

	BMI (kg/m^2)								Head circumference (cm)						
	10th	25th	50th	75th	85th	90th	95th	97th	3rd	10th	25th	50th	75th	90th	97th
Boys	13.6	14.7	15.8	17.0	17.7	18.2	18.8	19.5	35.1	36.8	38.4	40.1	41.7	43.3	44.9
	13.6	14.7	15.9	17.1	17.8	18.3	18.9	19.6	35.8	37.4	39.0	40.7	42.3	43.9	45.5
	13.7	14.8	16.0	17.2	17.9	18.4	19.0	19.7	36.1	37.8	39.4	41.0	42.6	44.3	45.9
	13.9	14.9	16.1	17.3	18.0	18.5	19.1	19.9	36.5	38.1	39.7	41.4	43.0	44.6	46.2
	14.0	15.0	16.2	17.4	18.1	18.6	19.3	20.0	36.8	38.5	40.1	41.7	43.3	45.0	46.6
	14.1	15.1	16.3	17.5	18.2	18.7	19.4	20.1	37.2	38.8	40.4	42.0	43.7	45.3	46.9
	14.2	15.2	16.4	17.6	18.2	18.8	19.5	20.2	37.5	39.1	40.8	42.4	44.0	45.6	47.3
	14.3	15.3	16.4	17.6	18.3	18.9	19.6	20.3	37.9	39.5	41.1	42.7	44.3	46.0	47.6
	14.3	15.4	16.5	17.7	18.4	19.0	19.6	20.4	38.2	39.8	41.4	43.0	44.7	46.3	47.9
	14.4	15.4	16.6	17.8	18.5	19.1	19.7	20.5	38.6	40.2	41.8	43.4	45.0	46.6	48.2
	14.5	15.5	16.6	17.8	18.5	19.2	19.8	20.6	38.9	40.5	42.1	43.7	45.3	46.9	48.6
	14.5	15.6	16.7	17.9	18.6	19.2	19.9	20.7	39.3	40.8	42.4	44.0	45.6	47.2	48.9
	14.6	15.6	16.7	17.9	18.6	19.3	19.9	20.8	39.6	41.2	42.7	44.3	45.9	47.5	49.2
	14.8	15.8	16.8	18.1	18.7	19.4	20.1	21.0	41.5	43.0	44.5	46.1	47.6	49.2	50.8
	14.8	15.7	16.8	18.0	18.7	19.4	20.1	21.0	43.2	44.6	46.1	47.6	49.1	50.6	52.2
	14.7	15.6	16.7	17.9	18.6	19.3	20.0	20.9	44.6	46.0	47.4	48.8	50.2	51.7	53.2
	14.6	15.5	16.5	17.7	18.5	19.2	19.9	20.9	45.8	47.1	48.4	49.8	51.2	52.6	54.0
	14.4	15.3	16.4	17.6	18.4	19.1	19.9	20.9	46.9	48.1	49.3	50.6	51.9	53.2	54.5
	14.3	15.2	16.3	17.5	18.4	19.1	20.0	21.0	47.7	48.8	50.0	51.2	52.4	53.6	54.9
	14.1	15.1	16.2	17.5	18.4	19.2	20.1	21.2	48.4	49.5	50.5	51.6	52.8	53.9	55.1
	14.0	15.0	16.2	17.6	18.5	19.3	20.2	21.3	49.1	50.0	51.0	52.0	53.1	54.1	55.2
	13.8	14.9	16.2	17.6	18.6	19.4	20.3	21.5	49.6	50.5	51.4	52.4	53.3	54.3	55.3
	13.6	14.8	16.2	17.7	18.7	19.5	20.4	21.6	50.2	51.0	51.8	52.7	53.6	54.5	55.4
	13.4	14.7	16.2	17.8	18.8	19.6	20.5	21.7	50.7	51.5	52.2	53.0	53.8	54.6	55.5
Girls	13.2	14.2	15.3	16.4	17.0	17.5	18.0	18.7	34.5	36.0	37.5	39.0	40.5	42.0	43.5
	13.2	14.3	15.4	16.5	17.1	17.6	18.2	18.8	35.1	36.6	38.1	39.6	41.1	42.6	44.1
	13.4	14.4	15.5	16.6	17.2	17.8	18.3	19.0	35.5	36.9	38.4	39.9	41.4	42.9	44.4
	13.5	14.5	15.6	16.7	17.4	17.9	18.5	19.2	35.8	37.3	38.8	40.3	41.8	43.3	44.8
	13.6	14.6	15.7	16.9	17.5	18.1	18.6	19.3	36.2	37.7	39.2	40.6	42.1	43.7	45.2
	13.7	14.7	15.8	17.0	17.7	18.2	18.8	19.5	36.5	38.0	39.5	41.0	42.5	44.0	45.5
	13.8	14.8	15.9	17.1	17.8	18.3	18.9	19.7	36.9	38.4	39.9	41.3	42.8	44.3	45.9
	13.9	14.9	16.0	17.2	17.9	18.5	19.1	19.8	37.2	38.7	40.2	41.7	43.2	44.7	46.2

Table 4 (continued)

BMI (kg/m^2)							Head circumference (cm)						
10th	25th	50th	75th	85th	90th	95th	97th	3rd	10th	25th	50th	75th	90th	97th
14.0	15.0	16.1	17.3	18.0	18.6	19.2	20.0	37.6	39.1	40.5	42.0	43.5	45.0	46.5
14.1	15.1	16.2	17.4	18.1	18.7	19.3	20.1	37.9	39.4	40.9	42.4	43.9	45.4	46.9
14.2	15.2	16.3	17.5	18.2	18.8	19.5	20.2	38.3	39.8	41.2	42.7	44.2	45.7	47.2
14.2	15.3	16.4	17.6	18.3	18.9	19.6	20.3	38.6	40.1	41.6	43.0	44.5	46.0	47.5
14.3	15.3	16.4	17.6	18.4	19.0	19.6	20.4	39.0	40.4	41.9	43.3	44.8	46.3	47.8
14.5	15.5	16.6	17.9	18.7	19.3	20.0	20.9	40.9	42.3	43.7	45.1	46.6	48.1	49.5
14.6	15.5	16.7	17.9	18.7	19.4	20.1	21.1	42.6	43.9	45.3	46.7	48.1	49.5	51.0
14.5	15.5	16.6	17.8	18.6	19.3	20.1	21.1	44.0	45.3	46.6	47.9	49.3	50.7	52.1
14.4	15.3	16.4	17.7	18.5	19.2	20.1	21.1	45.2	46.4	47.7	48.9	50.2	51.5	52.9
14.2	15.2	16.3	17.6	18.5	19.2	20.0	21.1	46.2	47.4	48.5	49.7	50.9	52.2	53.5
14.1	15.1	16.2	17.5	18.4	19.1	20.0	21.1	47.0	48.1	49.2	50.3	51.5	52.6	53.8
14.0	14.9	16.1	17.5	18.4	19.1	20.0	21.2	47.7	48.7	49.7	50.8	51.9	52.9	54.1
13.8	14.9	16.0	17.4	18.4	19.1	20.1	21.2	48.3	49.2	50.2	51.1	52.1	53.2	54.2
13.7	14.8	16.0	17.4	18.4	19.2	20.1	21.3	48.8	49.7	50.5	51.4	52.4	53.3	54.3
13.6	14.7	16.0	17.5	18.4	19.2	20.2	21.4	49.3	50.1	50.9	51.7	52.6	53.4	54.3
13.5	14.6	15.9	17.5	18.5	19.3	20.3	21.5	49.8	50.5	51.3	52.0	52.8	53.6	54.4

Northern Greece study and APDUA study. Similarly, in 2004 Lissau and colleagues showed that Greece has one of the highest prevalences of BMIs ≥ the 85th and 95th percentiles in adolescents, equivalent to that of the USA (Lissau et al. 2004). The results of the present study are in line with this report as the 85th BMI percentile of our data is higher than that of the CDC 2000 data, Euro-Growth Study, WHO 2006 Standard and IOTF 25 BMI in most gender-age groups.

The lack of local/national references in Greece for many years has led many fieldworkers to use the NCHS/CDC 1977–78 reference to assess and evaluate the growth of preschool children. The appropriateness of using NCHS reference values in countries outside the USA is questionable because of differences in ethnicity, culture and socioeconomic status (Cacciari et al. 2002; Neyzi et al. 2006). In this study, mean BMI values differ significantly from mean BMI values of the updated 2000 CDC data in nearly all gender-age groups. The Euro-Growth Study was designed as a multicenter, longitudinal, observational study in 1990 and attempted to construct European growth standards for the first 36 months of life with the enrollment of 2245 healthy, term neonates from 11 European countries (Van't Hof and Haschke 2000a). Greece was one of the participating countries, and the study results were released in 2000 (Cole et al. 2000; Van't Hof and Haschke 2000a, b). Our results of mean BMI had no significant differences from those of the Euro-Growth Study in most gender-age groups. Several countries considered the possibility of replacing their growth reference with the WHO Standard (Vignerova and Lhotska 2006; Wright et al. 2008) since it embodies a number of admirable principles, such as taking the breastfed child as the norm for growth and indicating that population differences in growth are avoidable, given optimum nutrition and living conditions. Comparing the median BMI of the WHO Standard with the mean BMI values of the present study, we found significant differences in nearly all gender-age groups. Although the comparison was preliminary and possibly not the most methodologically appropriate, it indicates that the WHO standard may not be simply transferable to a given population without further careful evaluation.

In the present study, a fluctuation in BMI values in almost all percentiles with increasing age was noticed. Fluctuations in weight percentiles though are much more common than height or head circumference changes. They are also more easily rectified (Legler and Rose 1998). In children, BMI decreases from birth until the point of 'adiposity rebound' at around 5–6 years and increases to the adult level by 18–20 years (Whitaker et al. 1998).

The definition of obesity in growing children is debatable, and probably BMI is not the most appropriate index (Bitsori

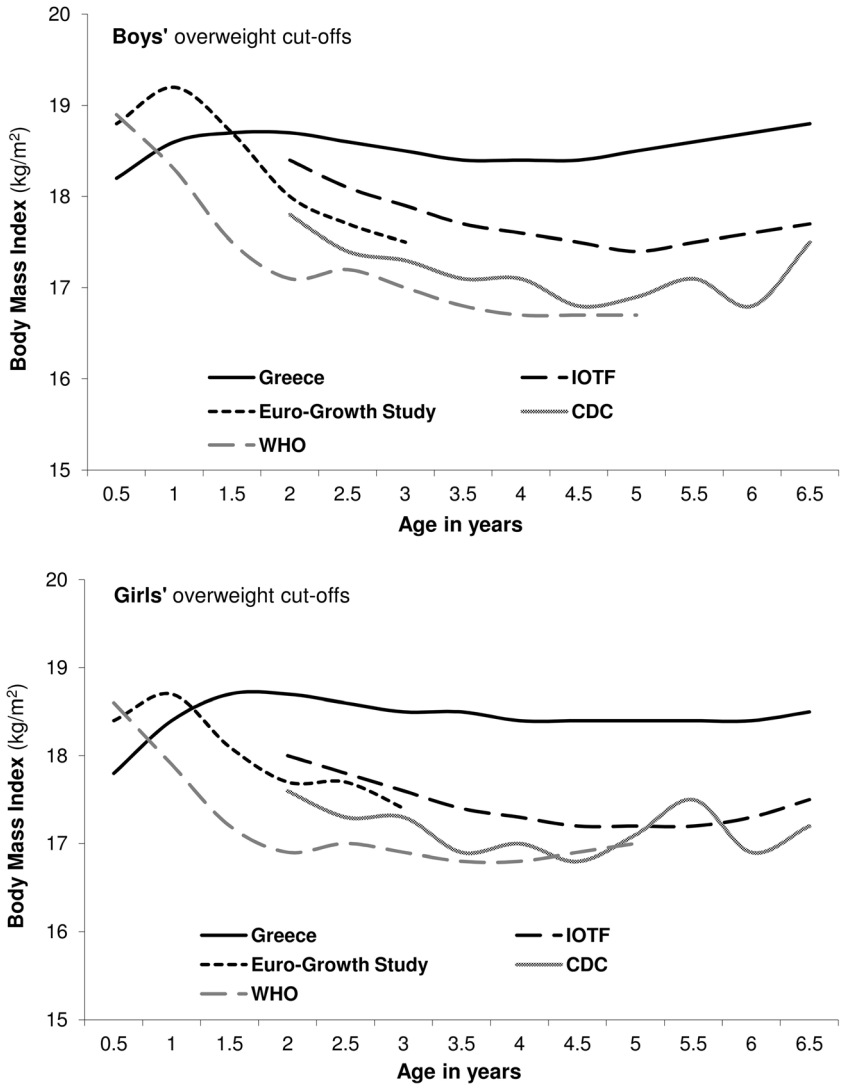

Fig. 3 Comparative illustration of 85th body mass index (BMI) percentiles of the present study, CDC 2000, Euro-growth Study, WHO 2006 Growth Standards and IOTF BMI 25 equivalent in boys and girls. CDC, Centers for Disease Control and Prevention; WHO, World Health Organization; IOTF, International Obesity Task Force

and Kafatos 2005; Lobstein et al. 2004). It is, however, the simplest and most widely accepted screening tool for the evaluation of obesity in children in both the clinical and the epidemiologic setting. The upper limit of BMI is another debatable point. In the US, the 85th and 95th percentiles of BMI have been recommended as cutoff points for overweight and obesity, respectively, in children (Ogden et al. 2002). The major problem with this definition, besides arbitrariness, lies in tracking trends over time. Since the prevalence of pediatric overweight is on the rise, the absolute BMI value at these percentiles tends to increase. Nevertheless, these percentiles can serve as a basis for comparison between different reference data. In an effort to establish an international definition of pediatric obesity, the IOTF obtained BMI data from large representative surveys in six countries, extrapolated the standards for adult overweight and obesity at age 18, and regressed the appropriate percentile cutoffs back through ages 2–18, giving the 25 BMI and 30 BMI equivalent for children (Cole et al. 2000). Although the resulting IOTF reference BMI values seem less arbitrary and more widely applicable, wide variation was found in the individual curves of the participant countries (Cole et al. 2000). This finding strengthens the case for the creation of country-specific reference data. In this study, we compared the 85th BMI percentile of our data with the 85th BMI percentile of CDC 2000 data, the Euro-Growth Study, WHO 2006 Standard and IOTF 25 BMI equivalent. The 85th BMI percentile for Greek infants and preschool children is higher than the other reference in most gender-age groups, fitting better with the Euro-Growth curve for the first 18 months, suggesting that the incidence of overweight among Greek children is probably higher, even in the first years of life.

Strengths and limitations

The main weakness of the current analysis on the construction of growth curves was the inability to take into account the

breastfeeding of infants, as this specific nutrition of infants (frequency and duration) was not reported in all relevant studies. Moreover, the time range of the data used in the construction of growth curves might be a possible limitation of this study, but the synthesis and combination of the samples of the seven cross-sectional and longitudinal studies that were carried out over a 17-year-period in Greece may be a common practice (Kuczmarski et al. 2000; Rojroongwasinkul et al. 2016). This should not occur during periods of increasing obesity and overweight trends or during periods of significant change and influence of the physical growth and overall health of the children and adolescents because of social turbulence, e.g., economic crisis or recession (Nobari et al. 2018; Rajmil et al. 2014, 2015; UNICEF 2014). Furthermore, another important motivation for the present work was the lack of current national growth patterns of preschool children, since we believe that those patterns would help, if used properly, to assess the health level of the Greek child population.

Conclusion

In conclusion, in this study we constructed growth curves for Greek infants and preschool children (0–6.7 years old) based on a nationally representative sample of adequate size and including a longitudinal component. Until a more reliable sample for this age group is available, the presented data can possibly serve as an additional reference for Greece. Much attention should be addressed to the observation that the upper BMI limits of Greek children are higher than any other available reference data, even at the youngest ages. However, these growth patterns will help healthcare professionals to assess and evaluate the health status of the Greek child population.

Compliance with ethical standards

Research involving human participants *Ethical approval:* All procedures performed in studies involving human participants were in accordance with the ethical standards of the Ethics Committee of the University of Crete & Harokopio University and with 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants (their parents) included in the study.

Disclosure of potential conflicts of interest The authors declare that they have no conflict of interest.

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